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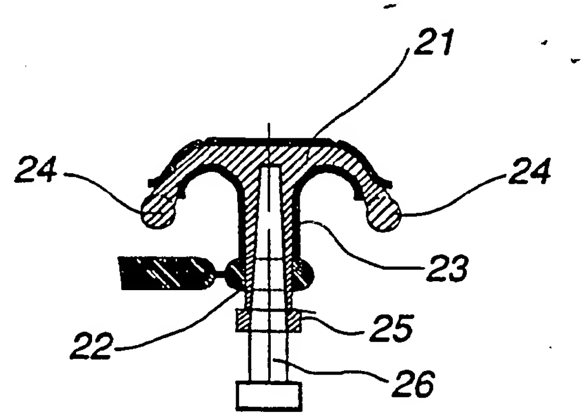

(57) Abstract

A method of removing a core from an object formed by injection moulding starting from a compound comprising a metallic and/or ceramic powder material. The outer contour of the object is formed against an external tool arranged in an injection moulding tool and at least the inner contour of an inner cavity is formed against a core (11, 21) provided in the injection moulding tool. The core consists at least partly of a leachable core material which is removed, wholly or partially, from the injection-moulded object by directing at least one jet of a leaching liquid against the leachable core material by means of one or more spray nozzles. The leachable core material is dissolved and flushed away and said nozzle is inserted successively into the inner cavity as the leachable core material is being dissolved and flushed away. The core is then removed in its entirety and the inner cavity exposed before said object is sintered and consolidated into the desired density by means of methods which are accepted within the

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Method of removing cores during injection moulding of objects starting from metallic and/or ceramic materials in powdered state

TECHNICAL FIELD

The invention relates to a method of removing a core from an object formed by injection moulding starting from a metallic and/or ceramic powder. The outer contour of the object has been formed against an external mould, arranged in the injection moulding tool used, in the form of an external tool and the inner contour of the object has been formed against a core arranged in the injection moulding tool.

BACKGROUND ART

During injection moulding, holes and other internal contours, hereinafter referred to as the inner contour, are formed against a core arranged in the injection moulding tool. A number of requirements are then made on the core:

- it must be shaping, that is, impart to the injection-moulded objects the desired inner contour,

- it should be able to be fixed in the desired position in the tool and remain in this position during and in connection with the injection moulding,

- it must not react with or adhere to the injection-moulded object, and

- it must be capable of being removed from the object after the forming without the inner surface or the inner dimensions being influenced.

Since injection moulding is a method of forming which is often used when an object is manufactured in larger series,

it is, in addition, advantageous if the core comprises parts to which members for handling the core before and in connection with the injection moulding, as well as for handling the core with the object injection-moulded around the core after the injection moulding, can be applied.

The first two requirements are usually fulfilled by a suitable material choice; possibly, a barrier and/or release layer is applied to avoid reaction or adhesion between the injection-moulded object and the core. The core is usually removed mechanically from the formed object by being withdrawn from the hole. The hole and the core must therefore have such a shape that the core for geometrical reasons can be withdrawn from the formed object after the injection moulding. Alternatively, a composite core, in which the different parts can be individually withdrawn from the hole after the forming, can be used.

Many inner contours have such a geometrical shape that they cannot be formed by means of cores which fulfil the requirements set up above although the cores are composed from a number of sub-cores. In addition, composite cores are usually very complicated and expensive. If, in addition, the other requirements made on the core regarding, for example, the possibility of fixation in the tool and handling, preferably automated handling in connection with the manufacturing process, are to be fulfilled, then the core will be rendered even more expensive and complicated.

In objects with inner contours of such a geometry, usually only the outer contour is formed during the injection moulding whereas the inner contour is formed by means of subsequent machining using methods such as boring, grinding, milling, cutting with a flame, plasma, laser or water jet, or electroerosive machining, sparking. In particular for ceramic materials, such machining, in those cases where it is practicable, is very time-consuming and expensive.

Further, it is known to remove cores from cast or injection-moulded objects by an at least partial dissolution of the core, by means of leaching, melting or evaporation of the same. Such leaching, melting or evaporation of the core often takes place before or in connection with driving off organic constituents included in the injection-moulded object, such as binders and/or softeners. After the above-mentioned treatment, the injection-moulded object is sintered and consolidated into the desired density by methods recognized within the powdermetallurgical and ceramic industries. A problem arising when a core is removed by means of leaching, melting or evaporation is that these operations are usually connected with a change in volume, preferably an increase in volume, of the core and/or the compound injection-moulded around the core. This volume change, which arises as a consequence of the temperature changing or by the core swelling in contact with the leaching liquid, results in the inner contour and/or all of the injection-moulded object being deformed. During melting or evaporation, the softening temperature of the organic constituents included in the injection-moulded object is often exceeded, which easily gives rise to deformations and renders this method unsuitable for the manufacture of accurately formed parts.

An object of the invention is to suggest a method whereby a core can be removed from injection-moulded objects without the inner shape or the dimensions being affected.

SUMMARY OF THE INVENTION

A ceramic and/or metallic object is formed by injection-moulding a compound which comprises a metallic and/or ceramic powder and, where necessary, softeners, binders and other additives which improve the workability of the compound, increase the green strength of the injection-moulded object, and facilitate the removal from the forming tool, etc. In this connection, the outer contour of the

object is formed against an external tool arranged in the injection moulding tool while at the same time at least the inner contour of one inner cavity is formed against a core arranged in the injection moulding tool. This core, which at least partly comprises a leachable core material, is removed after the forming by a treatment whereby the leachable core material is dissolved and removed from the injection-moulded object without the object or the inner contour being deformed. According to the invention, the core is removed from the injection-moulded object by directing at least one jet of a leaching liquid against the leachable core material by means of one or more spray nozzles, whereby the leachable core material is dissolved and flushed away, successively inserting the spray nozzle into the inner cavity according as the leachable core material is being dissolved and flushed away such that the inner cavity is exposed.

Since the leachable core material is flushed away by the flushing leaching liquid, its volume cannot change. At the same time, the contact time of the injection-moulded object with the leaching liquid is reduced in relation to the contact time in conventional leaching. Since the contact time of the leaching liquid with both the core before the disintegration and with the injection-moulded object is reduced considerably with the method according to the invention for removing cores from injection-moulded objects, the influence and the ensuing deformation of the injection-moulded object or its inner contour, which during normal leaching treatment destroys ceramic and/or metallic materials, is essentially eliminated. Further, the temperature of the injection-moulded part can be maintained below the softening temperature - Tg for amorphous and Tm for part-crystalline organic materials - of organic constituents included in the injection-moulded object. Therefore, deformations are avoided and parts with a high accuracy of shape can be manufactured.

In one embodiment of the invention, the core is formed around a permanent and stiff core element, preferably a core element in the form of a steel rod. This permanent and stiff core element is preferably arranged with a part which projects from the core, which increases the manageability of the core. This property is further enhanced by arranging part of the core element to project from the core formed around the core element. By forming the core around a permanent and stiff core element and by arranging the core element to partially project from the core, the possibilities of handling cores in a rational and efficient way are increased when manufacturing objects by means of injection moulding, both before the injection moulding,

- when forming the core,
- when possibly preparing the core with a barrier layer, a release layer or other coatings/measures to avoid reactions or adhesion between the core and the injection-moulded object,

and in connection with the injection moulding,

- when inserting the core into the injection moulding tool, and
- when fixing the core in the injection moulding tool, whereby the projecting core element and other projecting parts arranged on the core are adapted to be guided into guiding recesses or grippers arranged in the external tool,
- when removing from the injection moulding tool the core and the object injection-moulded around the core.

In an automated handling system, grippers may be arranged to seize the object by means of the above-mentioned projecting part of the stiff core element, whereby an efficient, well controlled and automated handling of the core and the injection-moulded object from the forming of the core to the removal of the core from the injection-moulded object is made possible by making use of the invention. When removing such a core comprising a stiff core element and a core formed around the core element, which core at least partly comprises leachable material which is partially dissolved

and flushed away by the above-mentioned flushing leaching liquid, the cavity and the stiff core element are exposed.

In one embodiment of the invention, a core is formed which at least partly comprises an organic polymer material. The core is inserted into an injection moulding tool and after an object has been formed by injection moulding in the tool, the organic polymer material is dissolved and the disintegrated core is flushed away in the manner described above by means of a leaching liquid, flushing through the above-mentioned nozzles, in the form of a suitable solvent.

In a preferred embodiment of the invention, a core is formed which comprises a water soluble material, such as a water soluble resin or another water soluble organic polymer material, a salt or a water soluble silicate binder. The core is inserted into an injection moulding tool and after an object has been formed by injection moulding in the tool, the core is removed from the injection-moulded object in the manner described above by supplying water through nozzles to dissolve the water soluble core material and flush away at least part of the disintegrated core.

The above-mentioned leachable or in certain cases water soluble core material is, in one embodiment of the invention, a binder which binds a core formed from a coarse-grained, preferably spherical powder. The core is inserted into an injection moulding tool and after an object has been formed by injection moulding in the tool, the core is removed from the injection-moulded object in the manner described above by dissolving the leachable binder by the flushing leaching liquid which is supplied through nozzles and which also at least partially flushes away the core disintegrated into a coarse-grained powder.

According to one embodiment of the invention, the injection-moulded object is sintered and consolidated by hot-isostatic pressing in a high-pressure furnace. If this hot-isostatic

pressing is carried out according to a method in which the injection-moulded object in connection with consolidation and sintering is enclosed in a layer of glass which is impenetrable to the pressure medium, the core can advantageously be made from a glass powder and a leachable binder. The binder is leached and removed in the manner described above, whereupon the glass powder is enclosed in the glass enclosure used during the hot-isostatic pressing.

FIGURES AND EXAMPLES

The invention will be described in greater detail in the following with reference to examples and the accompanying drawing. Figures 1 and 2 show two examples of objects which are injection-moulded around a core according to the invention. The figures show a stiff core element with projecting portions for fixing and handling the core and the object formed during forming around the core. The injection-moulded objects shown in the figures also comprise casting gates, for distributing the injected compound, which are removed in operations following the forming operation.

EXAMPLE 1

The manufacture of a rotor for a spinning jet in a composite material comprising silicon nitride and silicon carbide.

A core 11 was formed starting from a spherical glass powder with a grain size of 125 to 25 µm bonded by a water soluble resin such as a polyvinyl acetate resin. The resin was added in a content of 5.9 per cent by weight. The core was formed around a stiff core element 12 in the form of a steel bar. The core was formed with projecting parts 15 and the steel bar 12 was arranged with parts 16 projecting from the formed core 11. This facilitated the insertion, location and fixation of the core in the injection moulding tool by fitting one of the projecting pars of the steel bar into a corresponding recess in a withdrawable part of the steel

core 17 provided in the injection moulding tool, and by fitting the projecting parts 15 formed on the core 11 as well as the other projecting part of the steel bar into recesses (not shown) in the injection moulding tool.

Of course, it would also have been possible to form the core with recesses, into which had been fitted bars or similar projecting parts in the injection moulding tool to fix the core in the proper position in the tool.

A compound consisting of a ceramic powder in the form of a mixture with the composition 30 per cent by weight silicon carbide, 2 per cent by weight yttrium oxide and 68 per cent by weight silicon nitride suspended in a polymer mixture was injected into the injection moulding tool. The polymer mixture with a softening temperature exceeding 70°C comprised polyethylene and polypropylene and was added in a content of 16.0 per cent by weight to the compound injected.

After injection moulding, the binder was dissolved in the core 11 by supplying flushing hot, 40-60°C, water through nozzles and directing it towards the water soluble parts of the core. As the water soluble parts of the core were dissolved, nozzles were successively inserted further and further into the cavity. After that, the steel bar 12 was removed whereas the glass powder, at least partly, was allowed to remain in the cavity.

The injection-moulded ceramic object was then transferred to a further where it was heated under vacuum to a temperature of about 600°C in order to drive off the polymer mixture added to the ceramic powder and volatile residues of the core material.

After that, the rotor 13 was enclosed in a glass enclosure, comprising glass powder remaining from the core material, sintered and consolidated by hot-isostatic pressing at 1750°C and 150 MPa for 2 hours, after which the glass

enclosure was removed. Finally, the rotor 13 was cleaned by blasting.

EXAMPLE 2

The manufacture of pipe tees in silicon nitride.

A core 21 was formed by injection moulding of a water soluble resin such as a polyvinyl acetate resin around a stiff core element 22 in the form of a steel bar. The steel bar 22 was arranged with a part 26 projecting from the formed core 21, whereby the insertion of the core 21 into an injection moulding tool (not shown), intended for forming of the pipe tee, was facilitated.

The location and fixation of the core in the injection moulding tool were facilitated by the core being formed with projecting parts 24, 25 which were fitted into corresponding recesses (not shown) in the injection moulding tool. Of course, it would also have been possible to form the core with recesses into which bars or similar projecting parts of the injection moulding tool had been fitted to fix the core in the proper position in the tool.

A compound consisting of a silicon nitride powder suspended in a polymer mixture was injected into the injection moulding tool. To the silicon nitride, 2.5 per cent by weight Y_2O_3 and 0.5 per cent by weight Fe_2O_3 had been added. The polymer mixture comprised polyethylene and polypropylene and was added in a content of 16.3 per cent by weigh to the compound injected.

After the injection moulding, the core 21 was removed by supplying flushing hot, 40-60°C, water through nozzles and directing it towards the water soluble parts of the core. As the water soluble parts of the core were dissolved and removed, nozzles were successively inserted further and further into the cavity.

The injection-moulded pipe tee 23, freed from the core, was heated in vacuum to a temperature of about 600°C, whereby the polymer mixture used during the injection moulding was removed.

After that, the pipe tee 23 was enclosed in a glass enclosure, comprising a water soluble glass, was sintered and consolidated by hot-isostatic pressing at 1750°C and 150 MPa for 2 hours. After the hot-isostatic pressing the glass enclosure was removed by leaching in water. Finally, the pipe tee 23 was cleaned by blasting.

CLAIMS

1. A method of removing a core from an object formed by injection moulding starting from a compound comprising a metallic and/or ceramic powder material, wherein an outer contour is formed against an external tool arranged in an injection moulding tool and at least the inner contour of an inner cavity is formed against a core (11, 21) which is arranged in the injection moulding tool and which at least partly comprises a leachable core material which can be dissolved, wholly or partially, during a leaching operation following the injection moulding, **characterized** in that the core is removed from the injection-moulded object by directing at least one jet of a leaching liquid against the leachable core material by means of one or more flushing nozzles, whereby said leachable core material is dissolved and flushed away, that said nozzle is successively inserted into the inner cavity as the leachable core material is being dissolved and flushed away such that the inner cavity is exposed.

2. A method according to claim 1, **characterized** by a shaping core of leachable material arranged around a permanent and stiff core element (12, 22), preferably in the form of a steel rod, which core is at least partly dissolved and flushed away by said flushing leaching liquid, whereby the cavity and the stiff core element are exposed.

3. A method according to claim 1 or 2, **characterized** in that said core comprises a coarse-grained, preferably spherical powder, bonded together by a leachable binder, and that said leachable binder is dissolved by the flushing leaching liquid, whereby the core is disintegrated into a free-flowing powder which is at least partly flushed away from the injection-moulded object by the flushing leaching liquid.

4. A method according to any of claims 1 to 4, **characterized** in that said leachable core material is dissolved by a flushing leaching liquid and is at least partly removed from the inner cavity, whereupon said object is sintered and consolidated into the desired density by using methods which are accepted within the powdermetallurgical and ceramic industries.

5. A method according to claim 4, **characterized** in that said core comprises a glass powder bonded together by a leachable binder and said leachable binder is removed by means of said flushing leaching liquid, whereby the core is disintegrated into a free-flowing glass powder which is in part enclosed in a glass enclosure used during a subsequent hot-isostatic pressing.

6. A method according to any of the preceding claims, **characterized** in that said core is removed at a temperature which is lower than the softening temperature of the organic constituents included in the injection-moulded object.

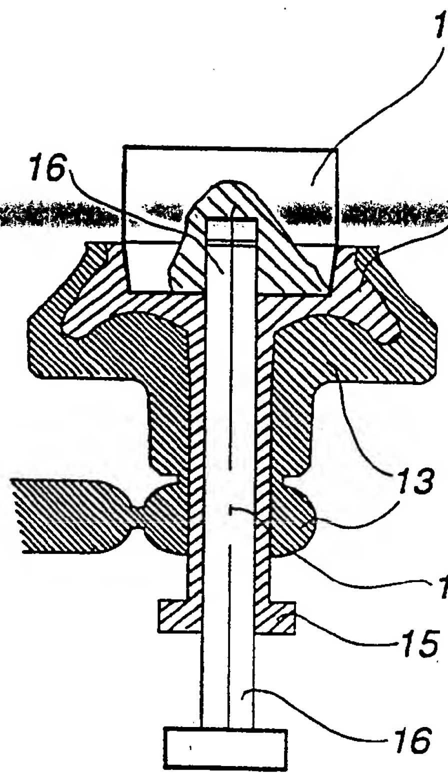

Fig. 1

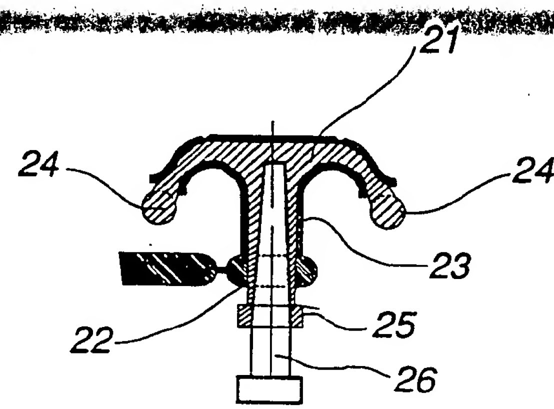

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00181

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: B22F 3/02, B22F 3/04, B22F 5/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: B22C, B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, WPIL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3963818 (TADAMI SAKODA ET AL), 15 June 1976 (15.06.76), column 2, line 6 - line 33; column 5, line 52 - line 56; column 6, line 10 - line 14	1,2,3
A		4,5,6
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Y	DE, A1, 2742203 (RASCHKE, ERHARD), 22 March 1979 (22.03.79), page 3, line 22 - page 4, line 16	1,2,3
A		4,5,6
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 June 1993	06 -07- 1993
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00181

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SE, B, 314782 (KAISER ALUMINUM & CHEMICAL CORPORATION), 15 Sept 1969 (15.09.69), page 3, line 17 - page 4, line 35; page 5, line 21 - line 30; page 8, line 22 - line 24	1,2
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Y	DE, C2, 3144960 (HONSEL-WERKE AG), 16 August 1984 (16.08.84), column 3, line 25 - line 46; column 4, line 11 - line 35, figures 1-4	2,3
A		1,4,5,6
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A	US, A, 5066454 (ANDREW D. HANSON), 19 November 1991 (19.11.91)	1-6
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